Groundwater – Surface-water Interactions

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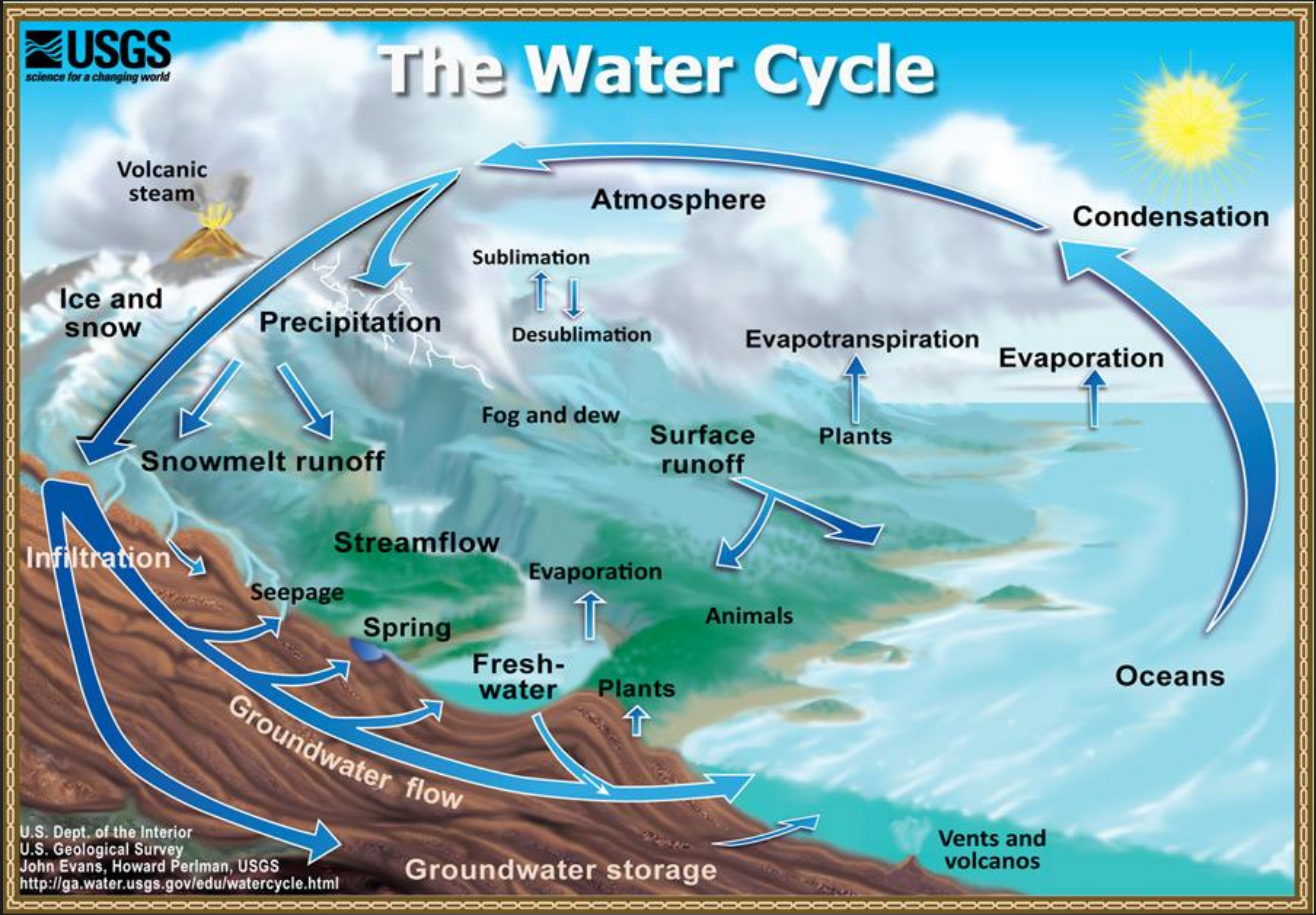
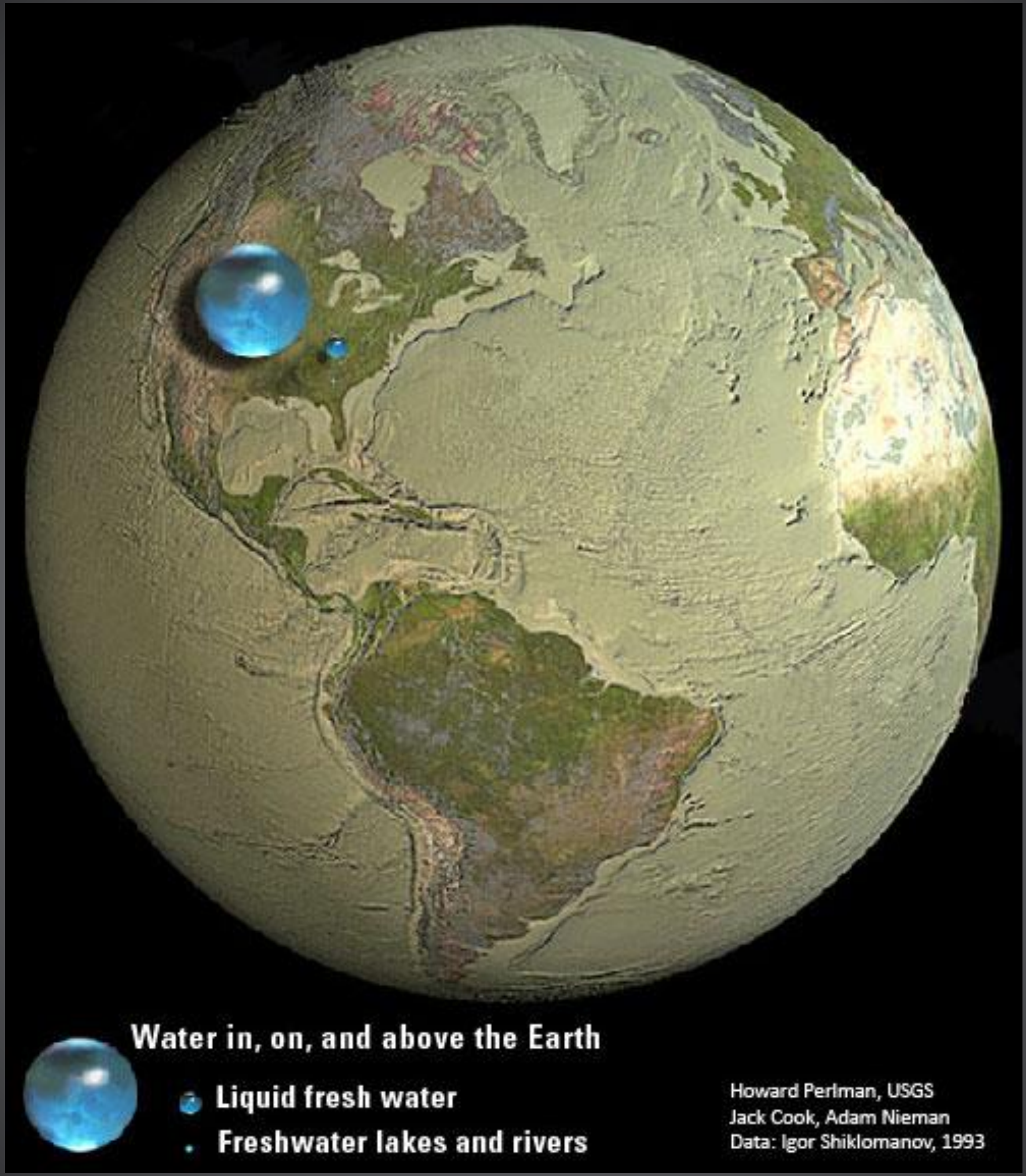
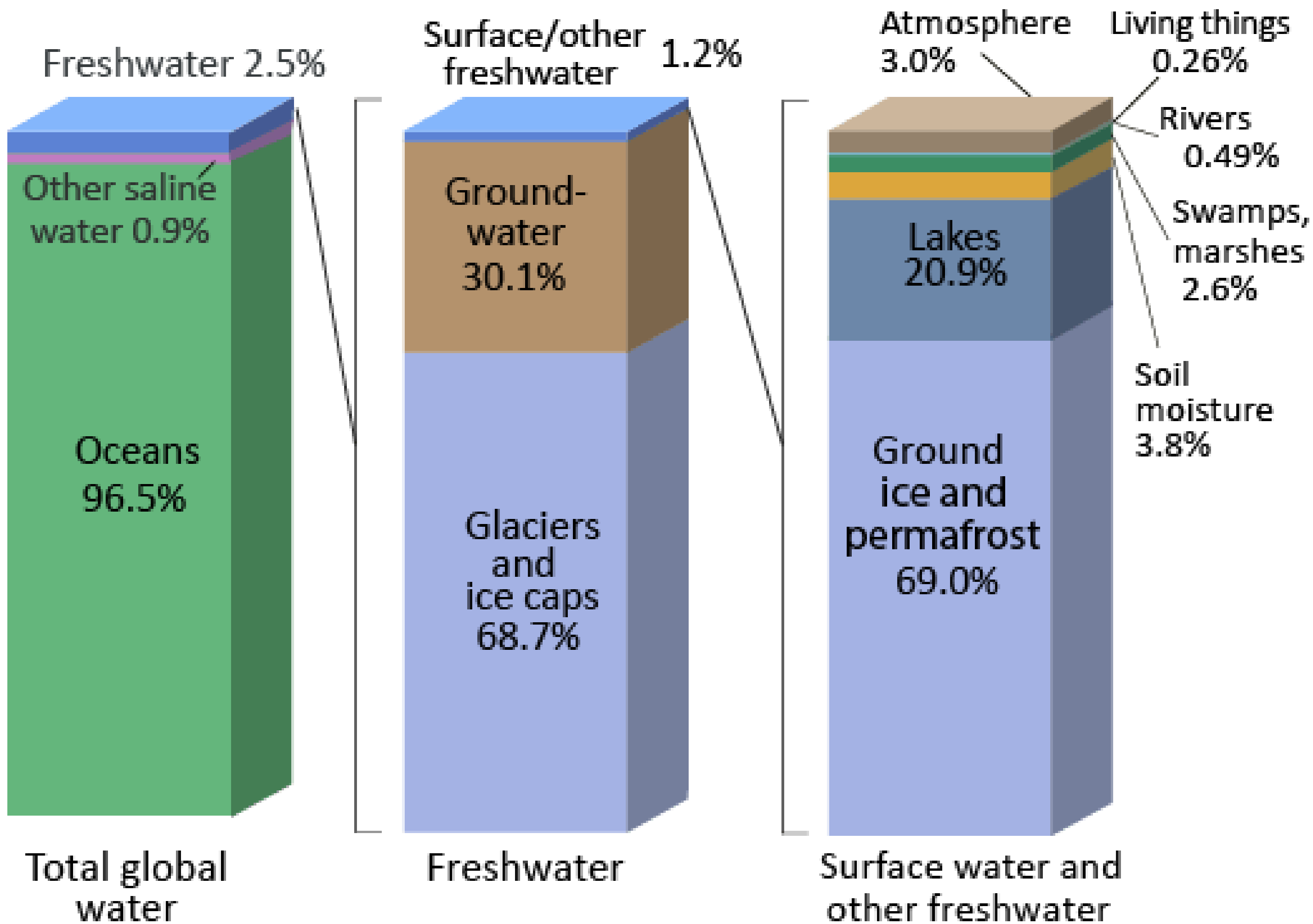


http://water.usgs.gov/edu/watercyclesummary.html



http://water.usgs.gov/edu/earthwherewater.html

Where is Earth's Water?



Source: Igor Shiklomanov's chapter "World fresh water resources" in Peter H. Gleick (editor), 1993, Water in Crisis: A Guide to the World's Fresh Water Resources.
NOTE: Numbers are rounded, so percent summations may not add to 100.

http://water.usgs.gov/edu/earthwherewater.html

Red River at Hwy. 259 Pecan Point 6/1/15 http://txktoday.com/news/monday-red-river-flood-update/

R R Boat Ramp, Lake Meredith: http://www.expressnews.com/150years/

GW-SW interactions:

- Interactions
  - Recharge
  - Discharge
  - Hyporheic Zone
- Examples
  - Recharge in the Hill Country
  - Tree-water interactions
  - Hydrogeochemistry and baseflows
- Why GW-SW interactions are so important

Groundwater – Surface-water Interactions: What do you think of?

Groundwater – Surface-water Interactions: What do you think of?

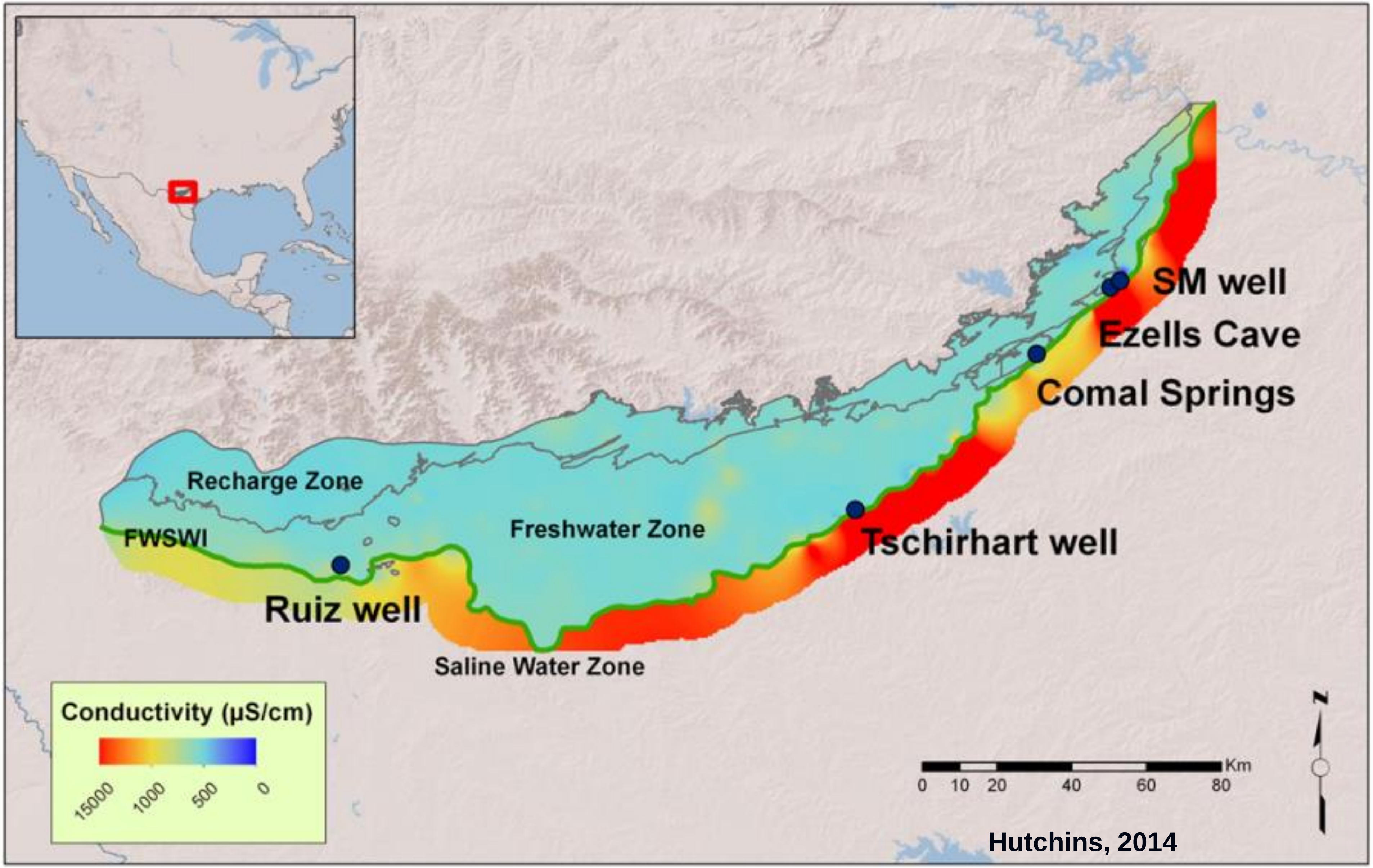
http://www.meadowscenter.txstate.edu/ExploreSpringLake.html

Groundwater – Surface-water Interactions: What do you think of?

http://water.usgs.gov/ogw/karst/aquifers/edwards/features

http://www.expressnews.com

Groundwater – Surface-water Interactions: What do you think of?



GW-SW interactions:

- Recharge
  - Infiltration/percolation
  - Sinkholes
  - ASR

Hill Country Example:
Tree-Water Interactions

- Discharge
  - Springs
  - Baseflow to streams
  - Pumping/extraction

Baseflow and Recharge Relationships

- Hyporheic exchange

Water and Nutrients

GW-SW interactions:

- Recharge
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  - ASR
- Discharge
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- Hyporheic exchange

GW-SW interactions:

- Recharge
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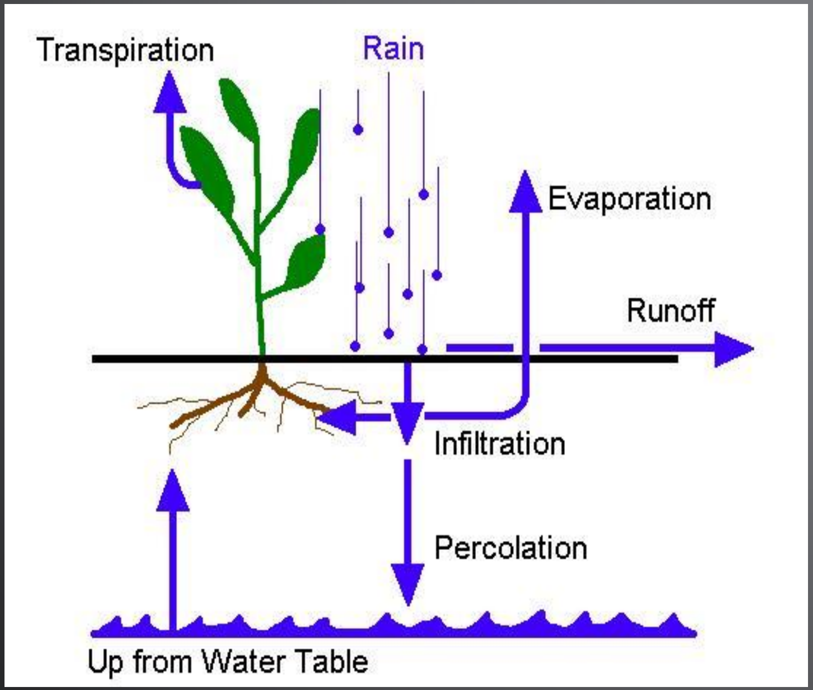
  - ASR

Macropores!



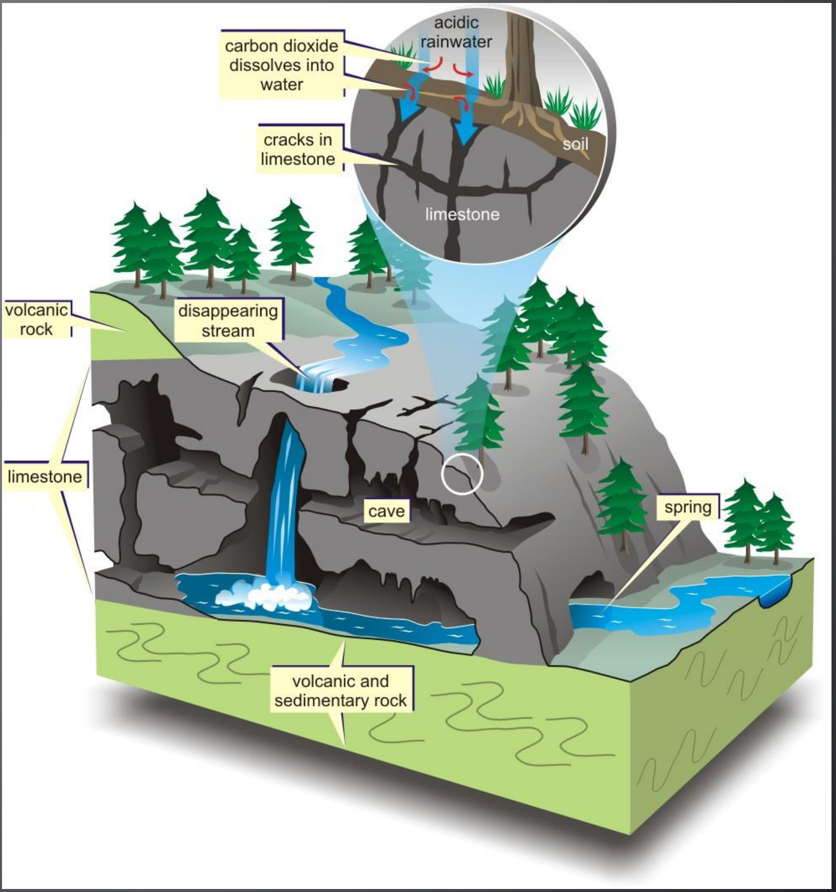
http://www.agronomy.lsu.edu/courses/agro2051/chap06.htm

GW-SW interactions:

- Recharge
  - Infiltration/percolation
  - Sinkholes
  - ASR

Megapores!

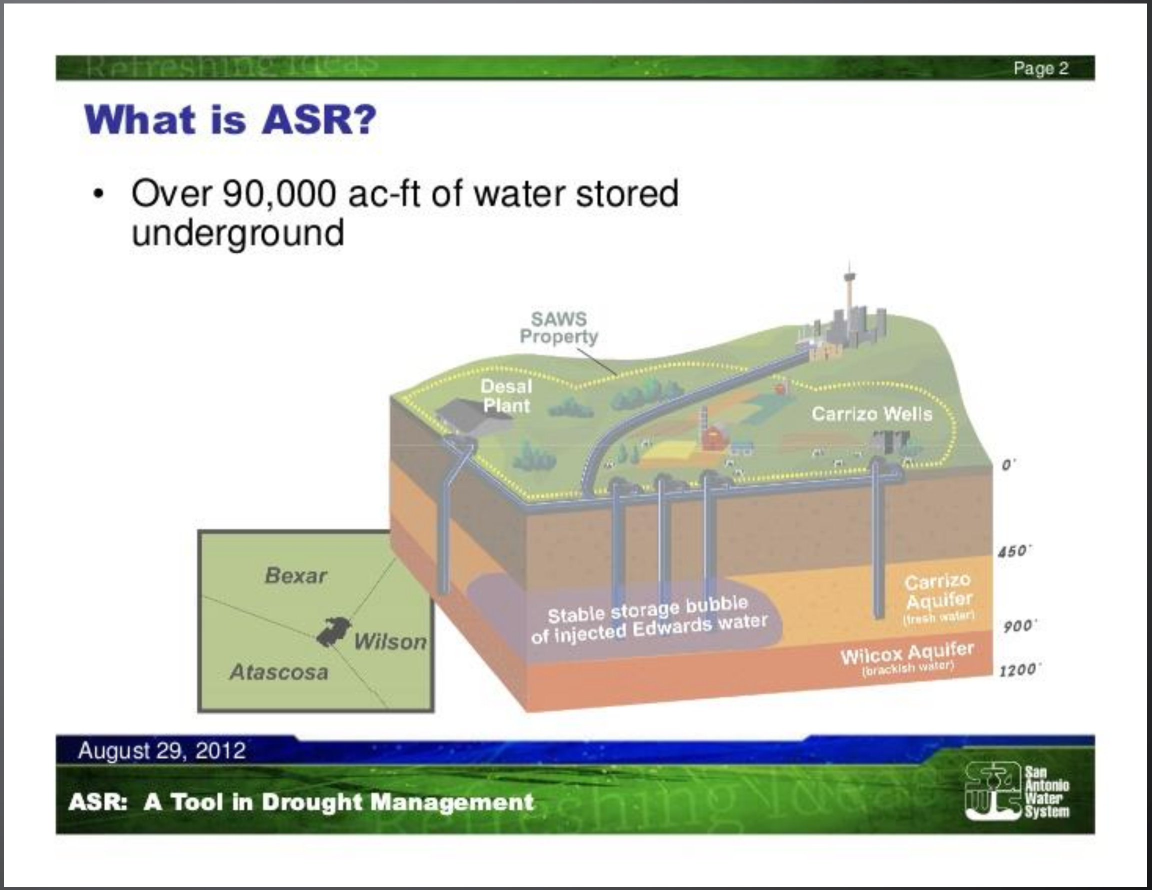
SW almost instantaneously enters the GW system.



GW-SW interactions:

- Recharge
  - Infiltration/percolation
  - Sinkholes
  - ASR

An example from San Antonio, TX



GW-SW interactions:

- Recharge
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- Discharge
  - Springs
  - Baseflow to streams
  - Pumping/extraction
- Hyporheic exchange

GW-SW interactions:

- Discharge
  - Springs
  - Baseflow to streams
  - Pumping/extraction

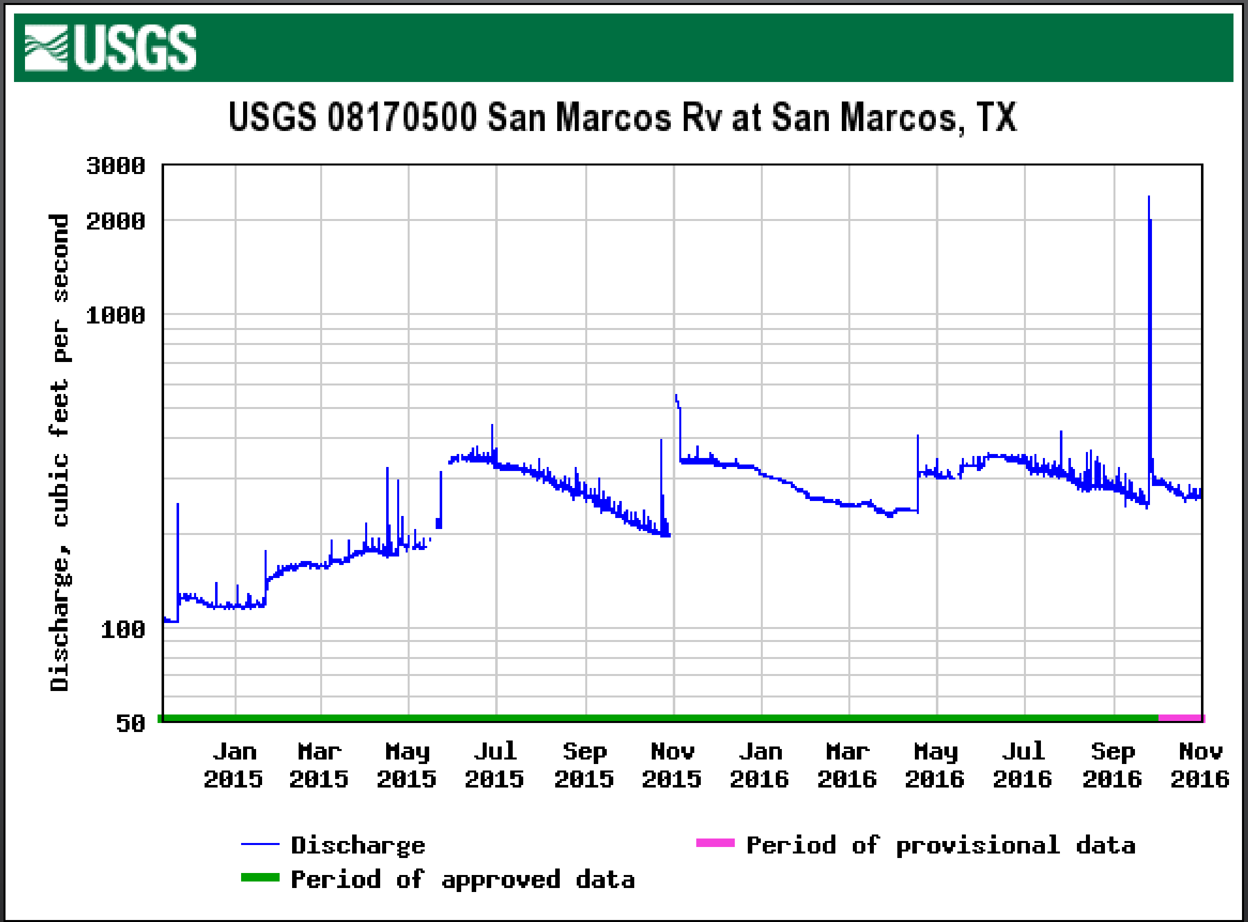
The ‘Charismatic Megafauna’ of GW systems, springs are indicators of aquifer health.

Andy Heatwole

GW-SW interactions:

- Discharge
  - Springs
  - Baseflow to streams
  - Pumping/extraction

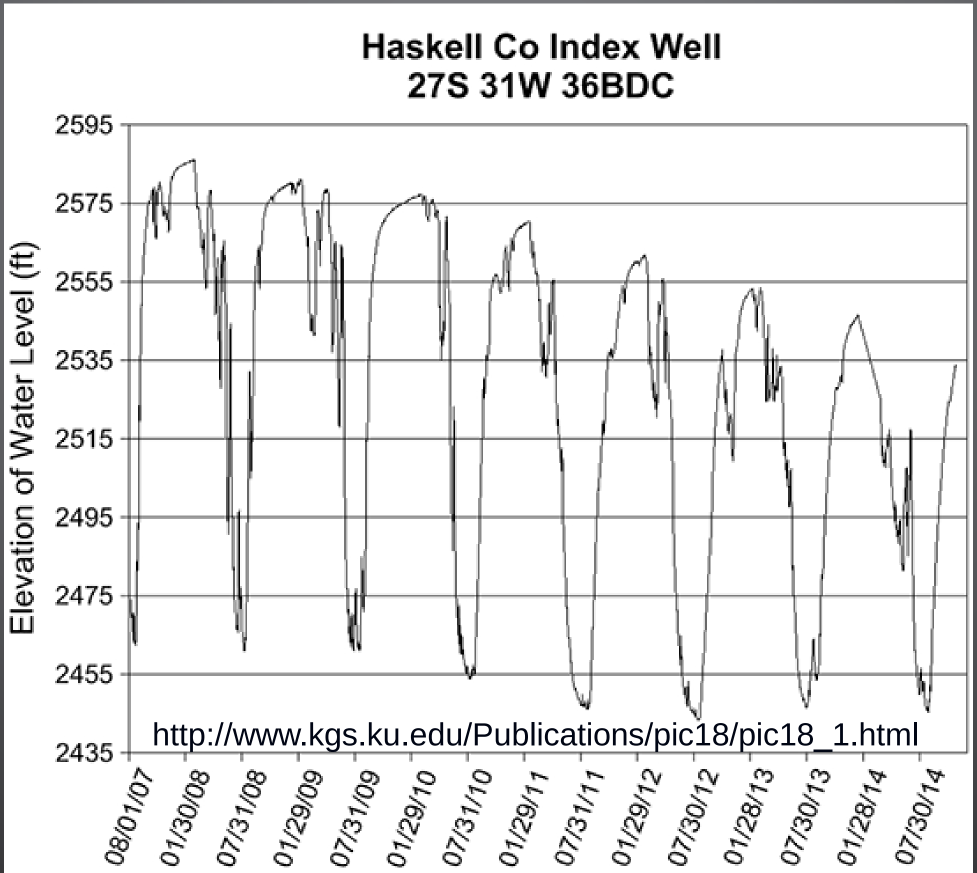
Baseflow is why streams continue to flow, even when it hasn't rained recently.



GW-SW interactions:

- Discharge
  - Springs
  - Baseflow to streams
  - Pumping/extraction

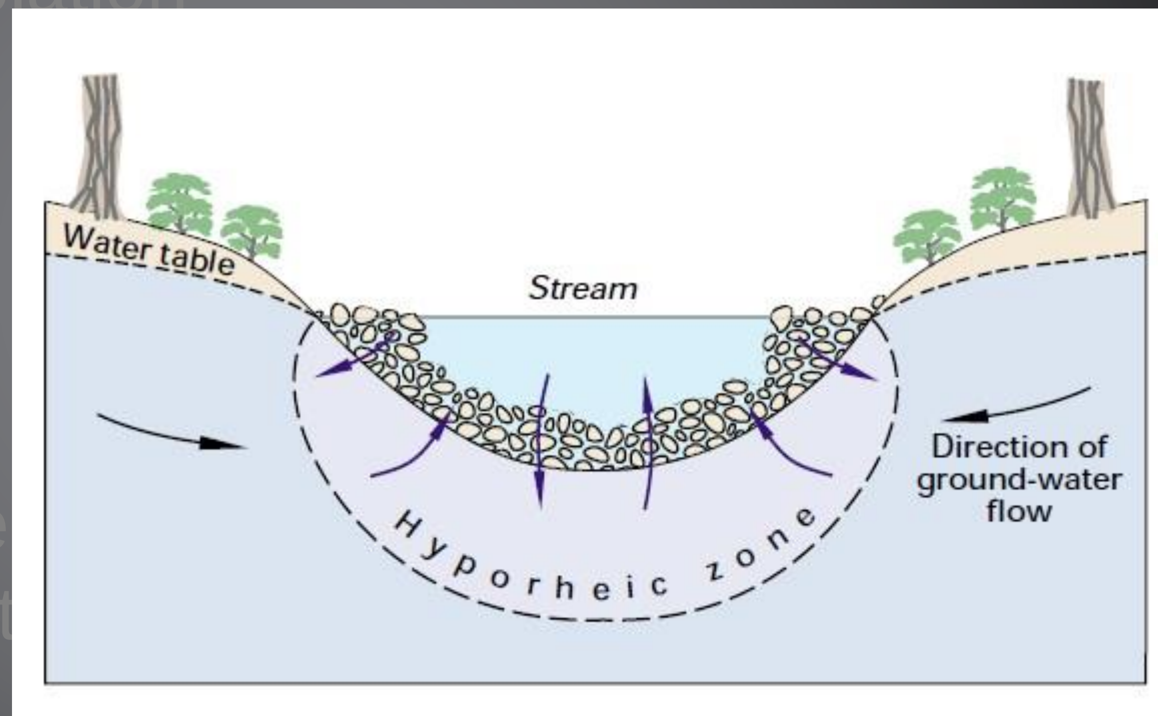
The GW-SW interaction that many people don’t see.



GW-SW interactions:

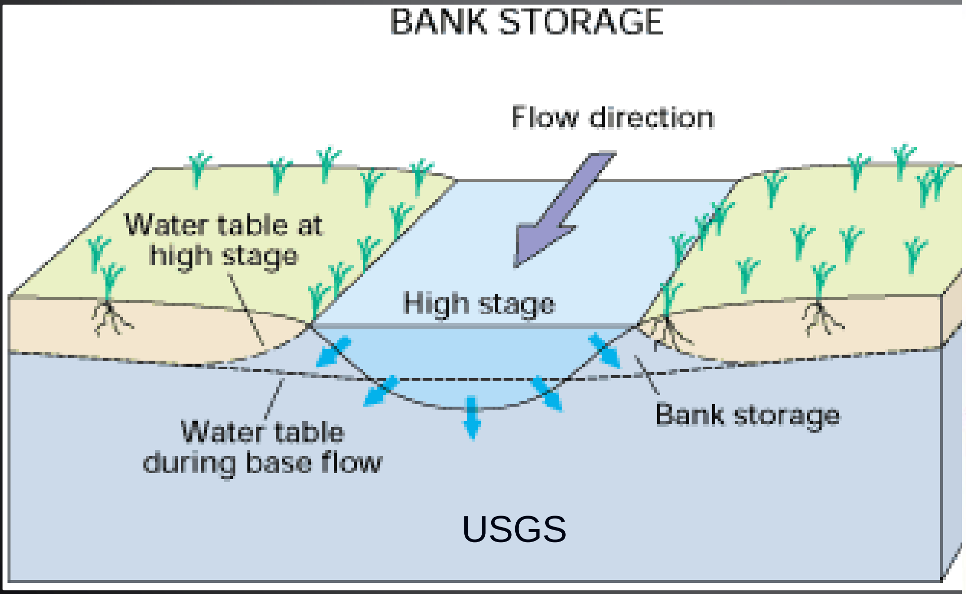
The Hyporheic Zone: an interface zone of dynamic boundaries and reactions.

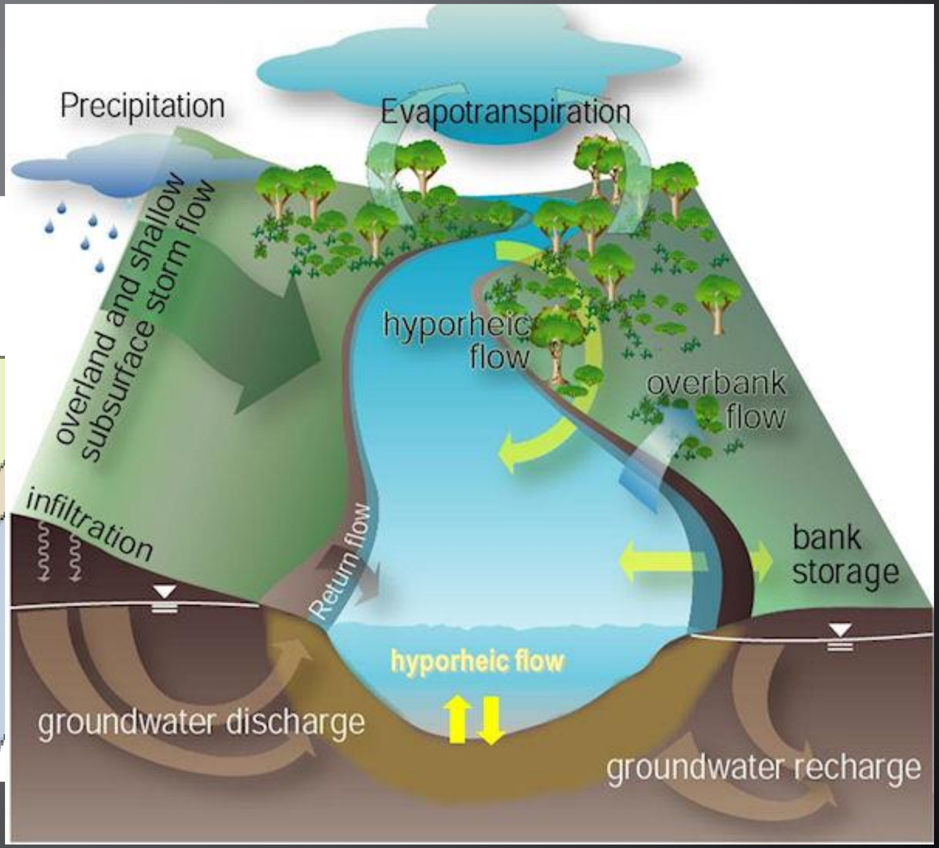
- Recharge
  - Infiltration/percolation
  - Sinkholes
  - ASR
- Discharge
  - Springs
  - Baseflow to stre
  - Pumping/extract
- Hyporheic exchange



http://www.bgs.ac.uk/research/groundwater/catchment/hyporheic_zone/home.html

- Hyporheic exchange:
  - Important for water quality and biotic health.
  - A steep geochemical gradient where rapid and important biogeochemical reactions occur.
  - Important for attenuating flooding and storm-waters (bank storage).

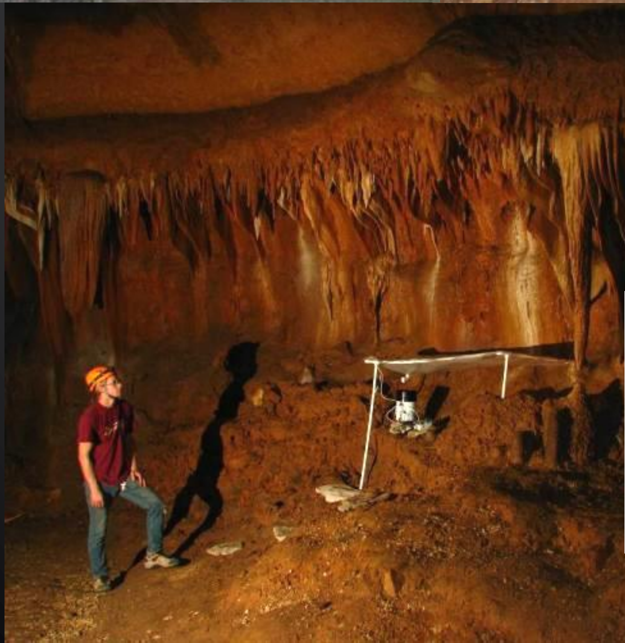




Case Studies of GW-SW Interactions:

- Research at Cave Without a Name (no, really!)

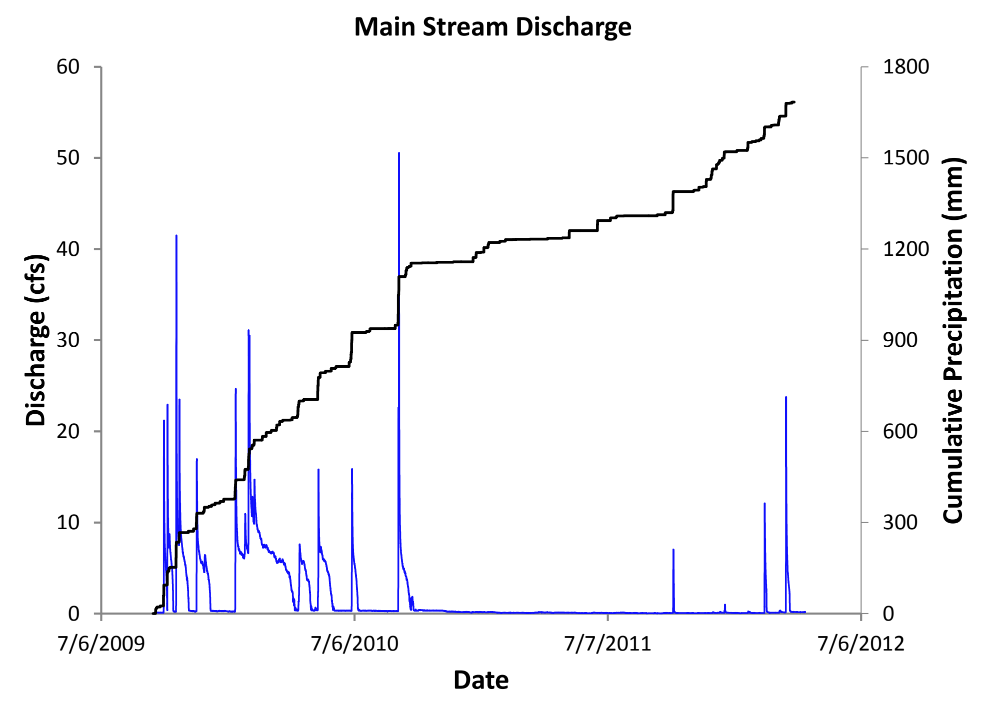
Cave Without A Name

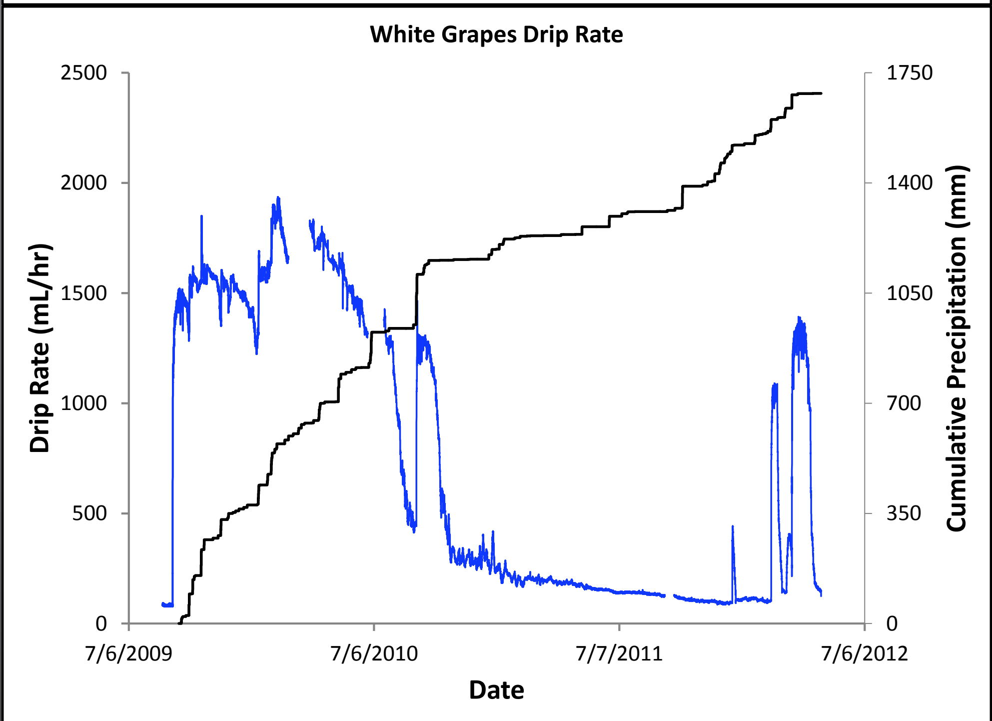


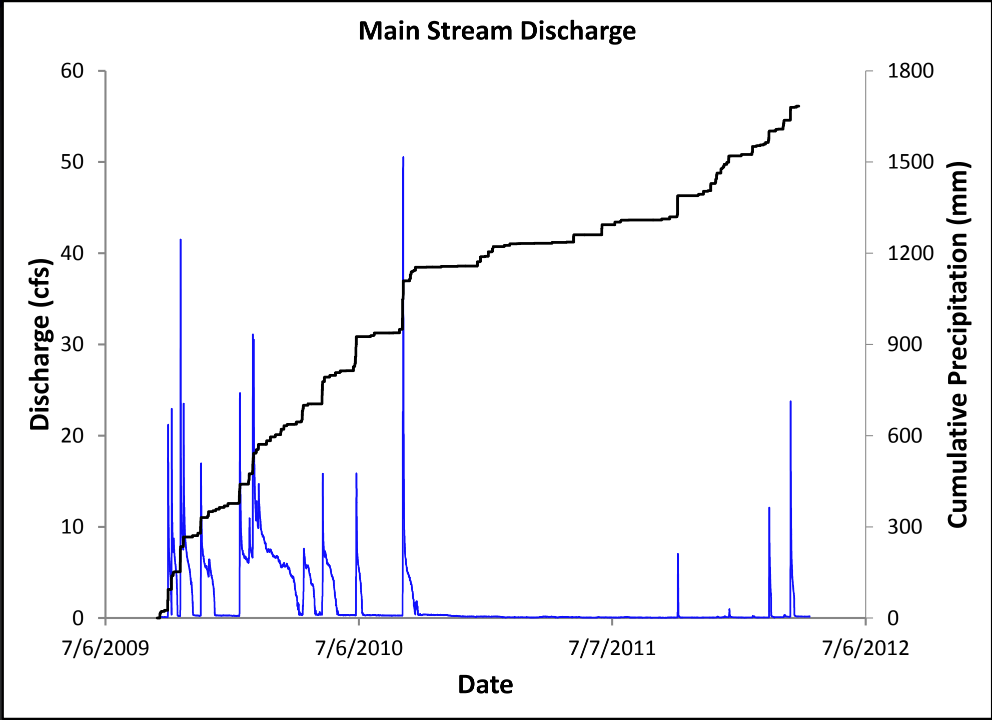
Kendall County, TX

Factors controlling recharge thresholds; can recharge be predicted at a site scale?

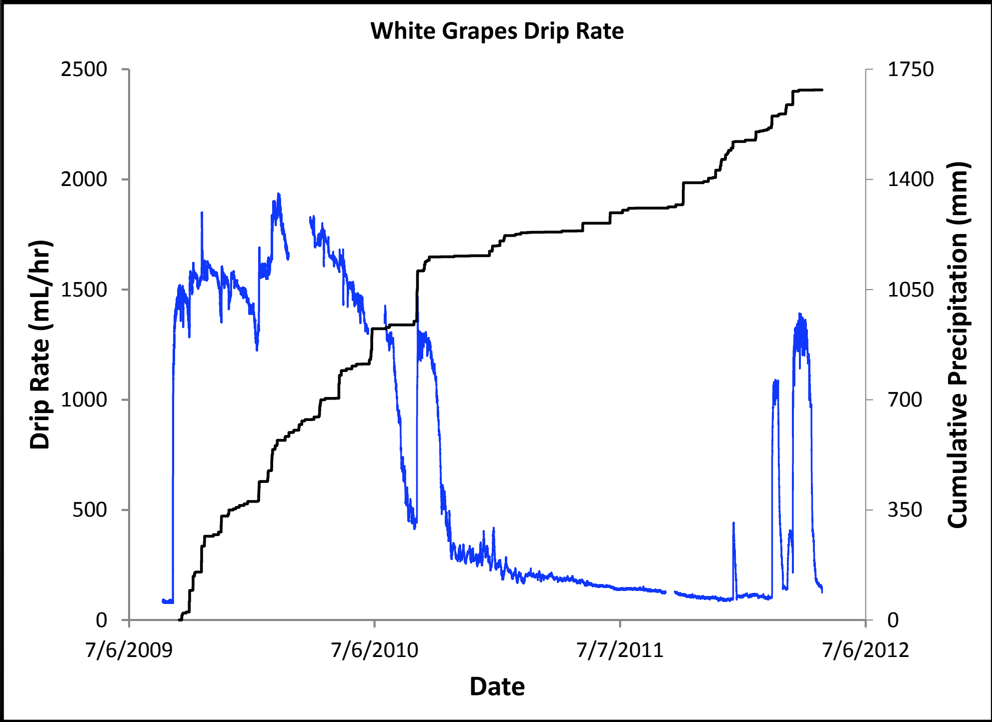
What is a recharge threshold, and how does it work?







Main Stream Discharge
Discharge (cfs)
Cumulative Precipitation (mm)
Date
60
50
40
30
20
10
0
1800
1500
1200
900
600
300
0
7/6/2009
7/6/2010
7/7/2011
7/6/2012



White Grapes Drip Rate
Drip Rate (mL/hr)
Cumulative Precipitation (mm)
Date
2500
2000
1500
1000
500
0
1750
1400
1050
700
350
0
7/6/2009
7/6/2010
7/7/2011
7/6/2012

Three variables are important in this type of model:

- P_s = Sum of precipitation during each event
- θ = Volumetric soil moisture [%] prior to precipitation event
- $PET_{12\text{-}14}$ = Sum of Potential Evaporation during the 12 to 14 weeks prior to a rain event
- Other variables were tested, but rejected

Mixed Effect Model (n=79)

Model Selection

Model	nPar	AIC	AICC	Akaike wt
Prob.=1	2	102.62	102.78	0.00
Prob.=P_S	3	68.49	68.81	0.00
Prob.=P_S+P_d	4	70.47	71.01	0.00
Prob.=P_S+θ	4	59.38	59.92	0.15
Prob.=P_S+PET_8	4	61.83	62.37	0.04
Prob.=P_S+P_d+θ	5	61.29	62.11	0.05
Prob.=P_S+P_d+PET_8	5	62.57	63.40	0.03
Prob.=P_S+θ+PET_8	5	56.92	57.74	0.45
Prob.=P_S+P_d+θ+PET_8	6	57.53	58.70	0.28

Variables in Selected Model

Coefficient	Estimate	Standard Error	z value	Pr (>|z|)
Intercept	-7.17	2.59	-2.76	0.006
P_s	0.20	0.05	3.68	< 0.005
θ	0.17	0.07	2.40	0.016
PET_s	-0.01	0.00	-1.83	0.067

Classification Table (Generating Data Set)

Observed	Predicted: No Response	Predicted: Response	% Correct
No Response	53	1	98.1%
Response	8	17	68.0%
Overall % Correct			88.6%

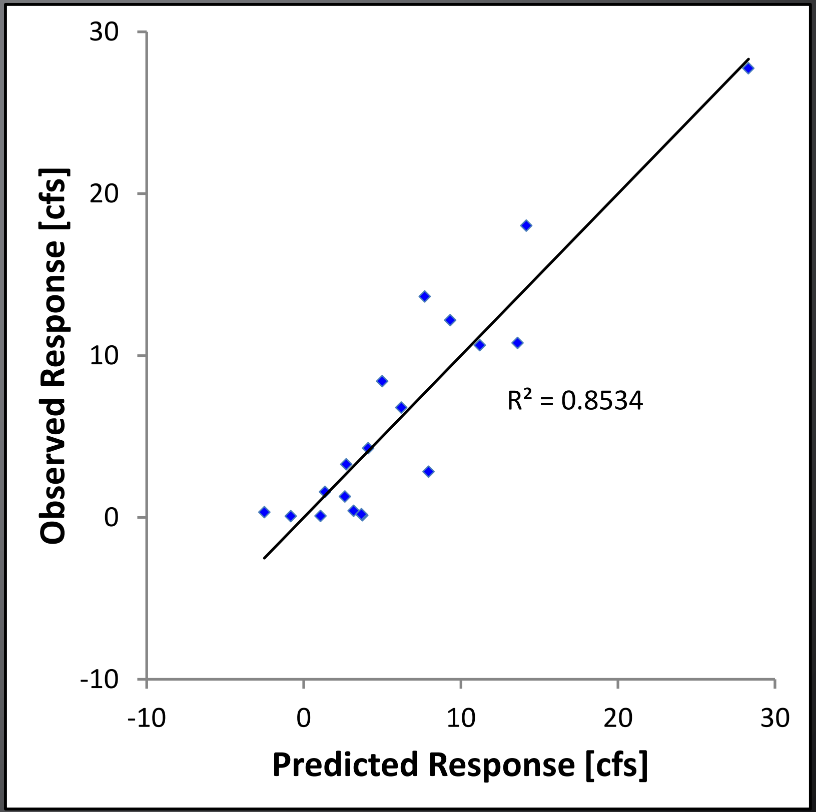
Classification Table (Non-Generating Data Set)

Observed	Predicted: No Response	Predicted: Response	% Correct
No Response	51	6	89.5%
Response	5	18	78.3%
Overall % Correct			86.3%

Multiple Linear Regression models are reasonably good at predicting the magnitude of a response

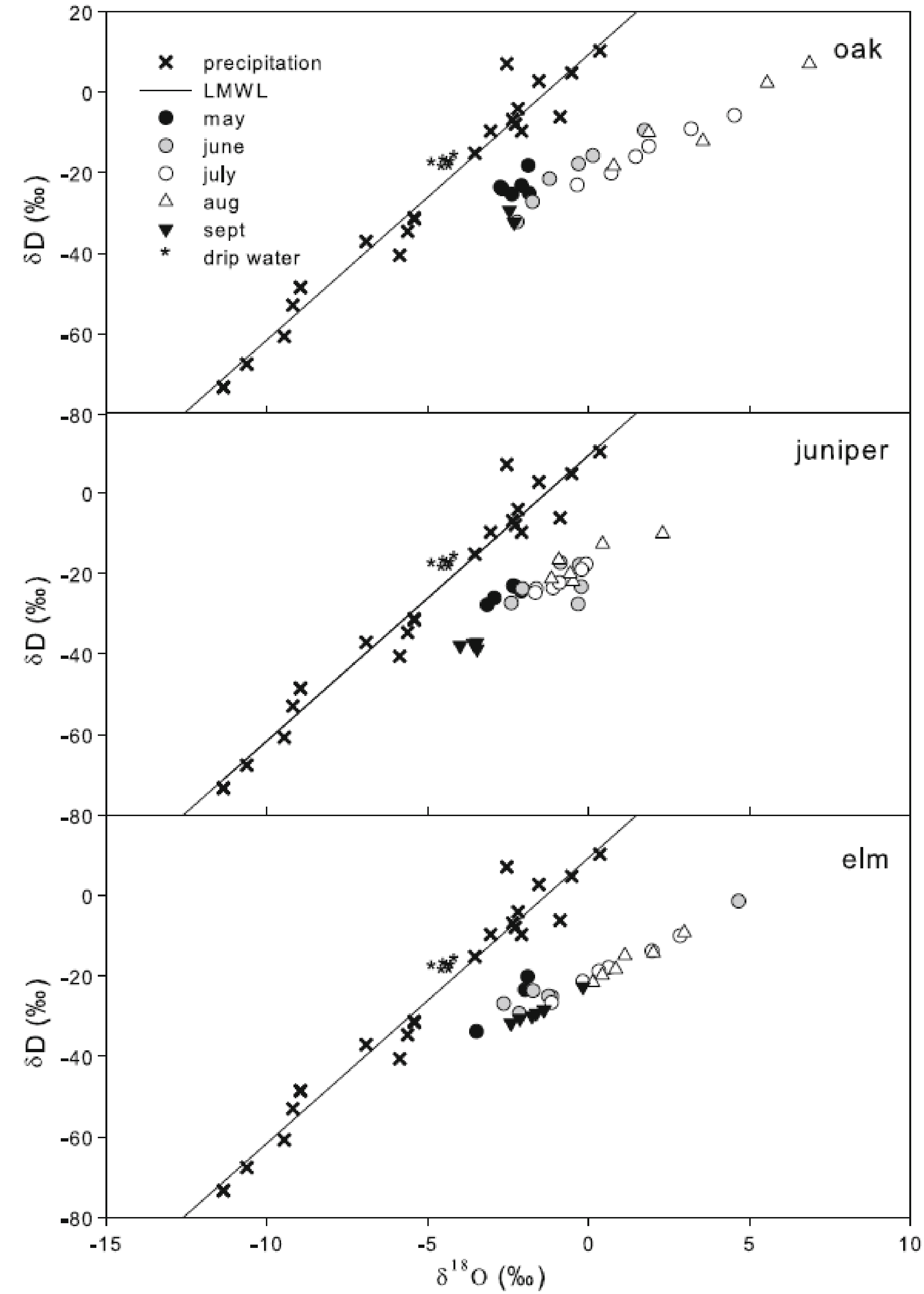
Most important predictor variables:

- P_s and PET_{10}



Stem water stable isotopes over time as evidence of GW-SW interactions

(Tree-water interactions research with Dr. Susan Schwinning)



GW-SW interactions in a VA cave system

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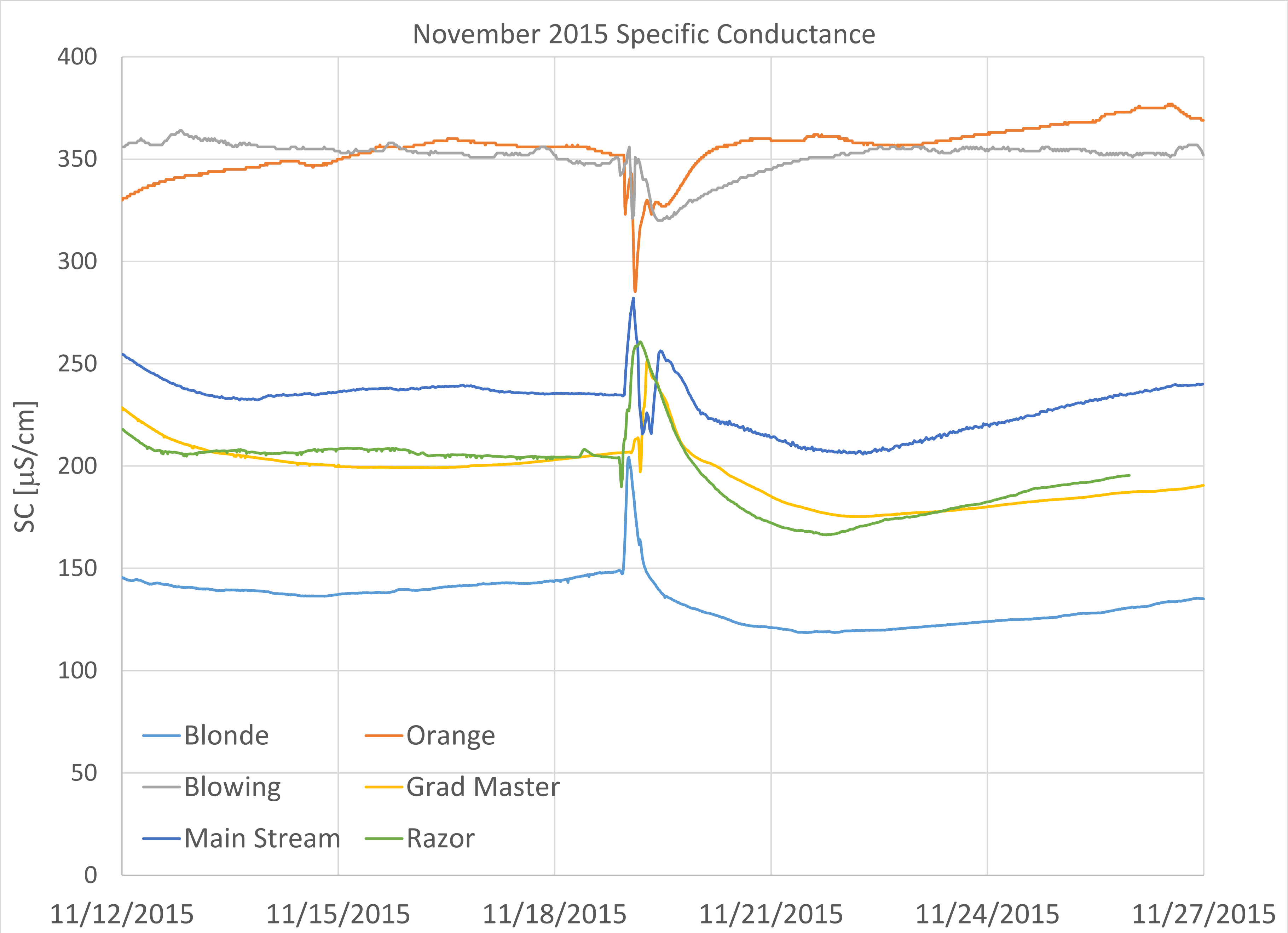
1) Department of Biology and Edwards Aquifer Research and Data Center, Texas State University, San Marcos, TX, USA

2) Department of Geosciences, University of Arkansas, 216 Ozark Hall, Fayetteville, AR, USA

3) Karst Science, Univerza v Novi Gorici, Vipavska 13, Si-5000, Nova Gorica, 5000, Slovenia

Conceptual model

- Build a network of instrumentation with the primary goal being long-term data
- Encourage added-value collaborations and smaller/shorter studies
- Leverage network for additional funds and research
- Develop a network of instruments and data: the research and collaborations will follow
- Create an open and well-documented database where data are available for all to access



November 2015 Specific Conductance
SC [µS/cm]
400
350
300
250
200
150
100
50
0
11/12/2015
11/15/2015
11/18/2015
11/21/2015
11/24/2015
11/27/2015
Blonde
Orange
Blowing
Grad Master
Main Stream
Razor

Summary:

1. GW-SW interactions involve the movements of water and transported materials (solutes, sediments, etc) into and out of the two systems.

2. Scales of interactions range from cm to km, and seconds to millennia.

3. Both GW and SW are integral components of the water cycle.

4. GW-SW interactions often occur in unexpected places and ways, and have unexpected consequences.

Why should we care?

1. GW-SW interactions influence the landscape, the water cycle, nutrient cycles, and aquatic ecosystems.

2. In Texas, water availability and quality is a huge issue, and will only continue to become more and more so.

3. Groundwater and surface-water regulation/management strategies do not recognize the full extent of these interactions, which will cause more and more problems.

4. GW-SW interactions affect more than just water budgets.

Acknowledgements:

Funding: Cave Conservancy Foundation, TX Advanced Research Program, USGS-NIWR.

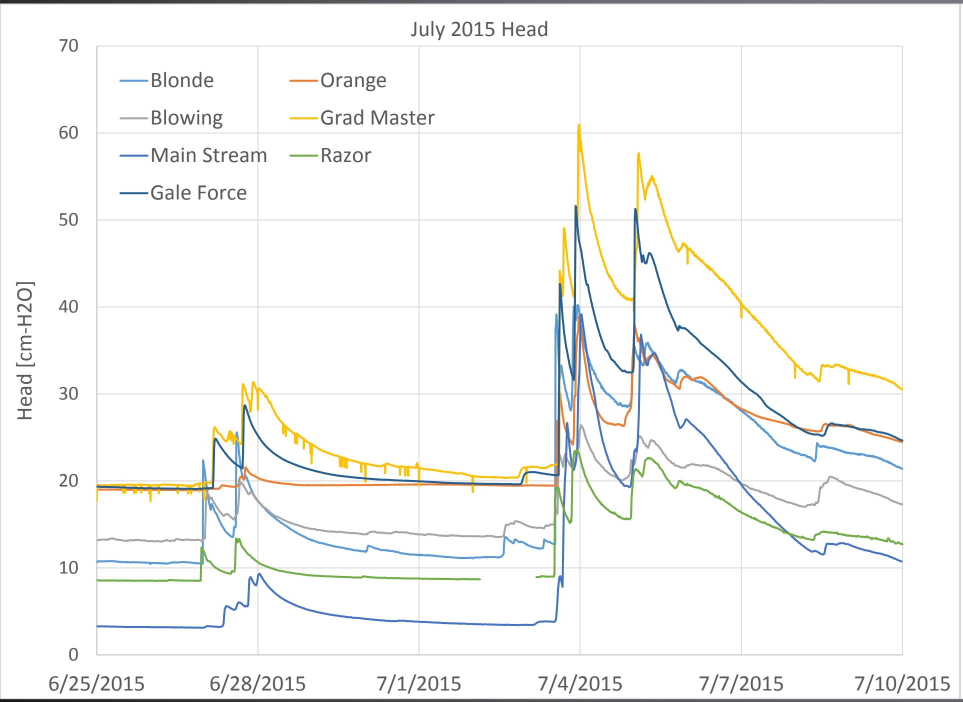
Collaborators: Matt Covington, Brett Gerard, Weston Nowlin, Susan Schwinning

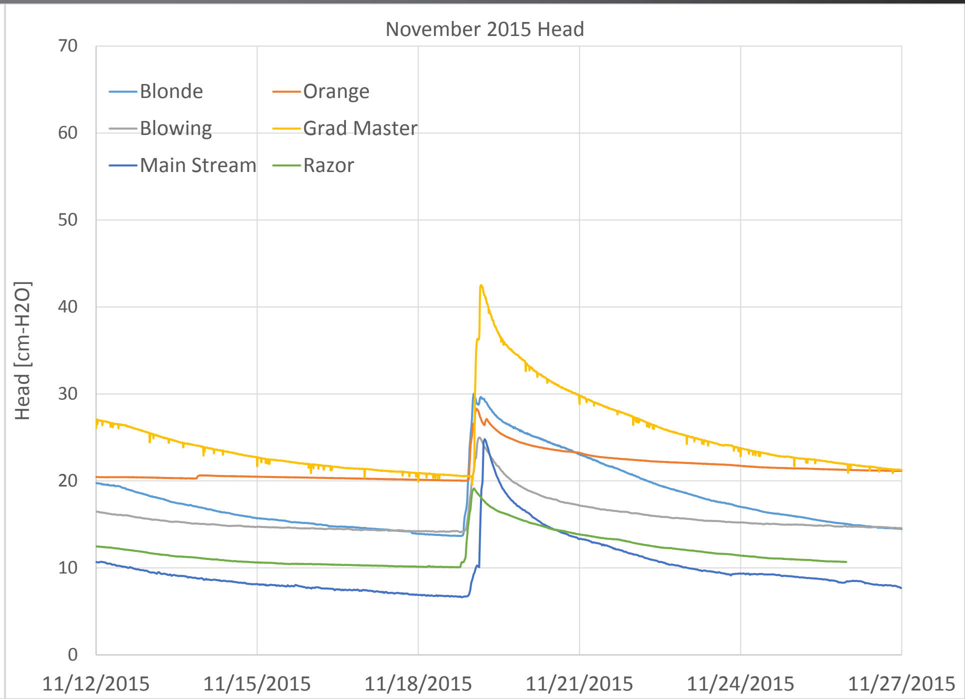
Field and Lab Assistance: Stephen Curtis, Heather Dammeyer, Ben Hutchins, Kelly Kukowsky, Katie Junghans, Lauren Loney, Hank Marley, Jacob Martin, Gabrielle Timmins, Ben Tobin, Philip Ramirez

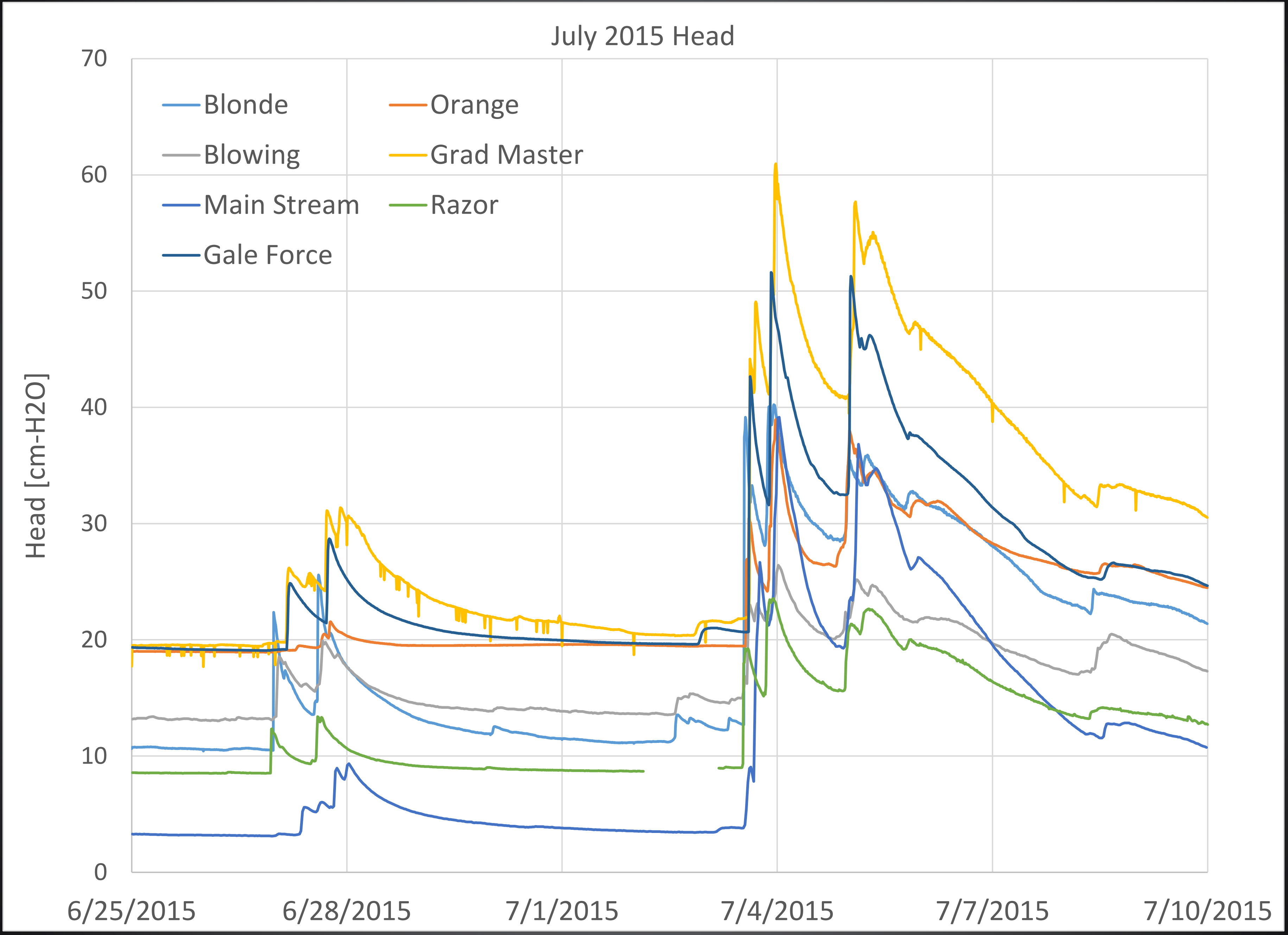
Mike Burrell: Manager of Cave Without A Name
Tom Summers: Owner of Cave Without a Name


Thank you!

Preliminary Data







July 2015 Head
Head [cm-H2O]
70
60
50
40
30
20
10
0
6/25/2015
6/28/2015
7/1/2015
7/4/2015
7/7/2015
7/10/2015
Blonde
Orange
Blowing
Grad Master
Main Stream
Razor
Gale Force